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Transmission Association to Meet on Mount Tamalpais.

THE decision of the Executive Committee of the Pacific Coast Electric Transmission Association to hold its coming Fourth Annual Convention at the Tavern of Mount Tamalpais, across the bay from San Francisco calls for more than passing notice of the charmingly situated place where the electrical transmission fraternity of the Far West, with its allied interests, will meet on Tuesday and Wednesday, the 19th and 20th, respectively, of June. It is concerning Mount Tamalpais that Marsden Manson, C. E., whose name is most familiar in Pacific Coast engineering circles, has written in *Appleton's Popular Science Monthly* for May, from which much of the descriptive matter which follows has been taken.

PROSPECT POINT.—A VIEW FROM NEAR THE SUMMIT OF TAMALPAIS.

Mount Tamalpais is the southern and terminating peak of the westerly ridge of the Coast Range, which confronts the Pacific Ocean from the Golden Gate to the Oregon line. Its outlines form the bold headlands which skirt the Golden Gate and adjacent waters to the north, and which bound the peninsula constituting Marin county. The spurs extending to the east reach the shores of the Bay of San Francisco, and enclose small alluvial valleys of great fertility and beauty. In some instances these valley lands are fringed by tidal marshes, in part reclaimed and under cultivation.

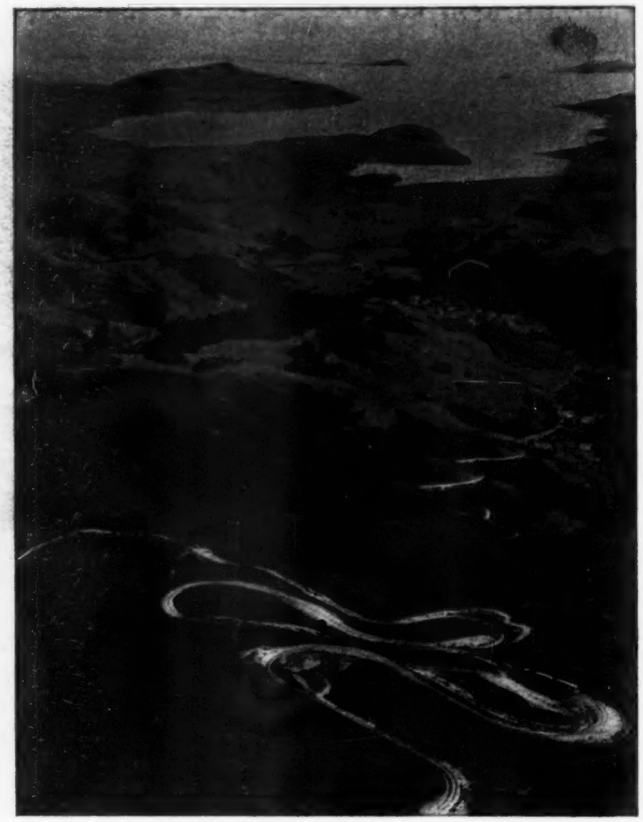
The top of the mountain breaks into three distinct peaks, each reaching an altitude of nearly half a mile above sea level, although bounded on three sides by tidal waters. No land points visible from the summit, except those bounding the apparent horizon, reach equal or greater altitude. The mountain is therefore a marked feature from all parts of the area visible from its summit, which area has an extent of about 8000 square miles.

The westerly group of islands, opposite the Golden Gate, are the Farallones. The bold headland northwest of the Gate is Point Reyes; it protects from the north and northwest winds the anchorage known as Drake's Bay. The strip of water between the adjoining peninsula and the mainland is Tomales Bay.

The most westerly headland south of the Golden Gate is San Pedro Point, and the prominent headland farther south is Pescadero Point. The whole of San Francisco Bay is visible from Mount Tamalpais, except a few sheltered nooks and portions behind islands.

The tidal area inside the Golden Gate is about 740 square miles at high tide; this includes that portion which extends east of the Coast Range into the valley of California, and known as Suisun Bay; this bay is connected with San Francisco Bay through the Straits of Carquinez and San Pablo Bay. Emptying into Suisun Bay at its easterly end are the Sacramento and San Joaquin Rivers. Thus the tidal waters washing the base of Mount Tamalpais are connected with the interior valley of California, and tributary to them are about 1200 miles of navigable channels, tapping the central part of the State.

From the summit of this peak the eye sweeps the horizon of the Pacific Ocean for nearly 150 degrees. To the northwest, north and northeast lie Petaluma, Santa Rosa, Sonoma and Napa Valleys, the view over these being



THE BOW-KNOT ON THE TAMALPAIS SCENIC RAILWAY.

bounded by the ridges inclosing them. To the east are the Straits of Carquinez, the outlet of the 58,000 square miles of drainage of the Sacramento and San Joaquin Rivers, and the only water gap in the entire perimeter.

From the east to the south lie the slopes of the Contra Costa hills and the ranges bounding the drainage into the Bay of San Francisco, and including the Santa Clara Valley, thus embracing a magnificent view of the garden spots of California, and the cities and towns around the bay—the homes of about one-third the population of the State. Three prominent peaks mark the limits of the land view: Mount Hamilton, the site of the Lick Observatory of the University of California; Mount Diablo, the base and meridian of the United States land surveys of central California; and Mount St. Helena, a volcanic peak the summit of which is common to Napa, Sonoma and Lake counties, and whose spurs are noted for their quicksilver mines, mineral and hot springs.

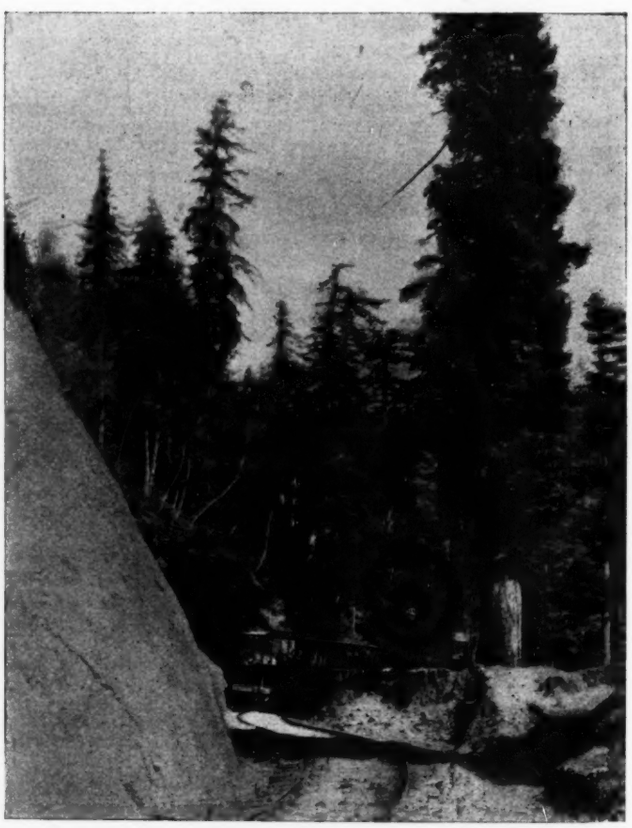
The plant life of the immediate Tamalpais region is abundant and interesting; the flowering plants are represented by about 80 orders, 350 genera, and from 700 to 800 species, of which about 100 are trees and shrubs.* Some of the Sierra forms occur on Mount Tamalpais, and it is also the locus of the most southerly extension of certain boreal species. Owing to the wide range of temperature, moisture conditions and exposures, many of these plants can be found in bloom during every week in the year. During the warm, moist autumn and winter the hardiest species bloom from October to April in protected areas, and in the cold, exposed areas these same species require the heat of the season from April to September to bring them into bloom. Thus, within a radius of four or five miles from the summit there is not a week in the year when the flowers of certain species can not be gathered—this in face of the fact that during the months of December, January and February the summit may be covered with sleet or snow for a day or two at a time.

*Estimated by Miss Eastwood, curator of the Department of Botany of the California Academy of Sciences.

Mount Tamalpais is therefore a point of great interest to the sight-seer, the tourist and the student of Nature.

TO REACH THE SUMMIT.

For many years a trail has existed from Mill Valley to the summit, and another from Ross Valley, both practicable for pack mules. Later the Ross Valley trail was improved so as to be practicable for light vehicles, but these did not answer the needs of the increasing travel, and in 1895 the Mill Valley and Mount Tamalpais Scenic Railway Company was organized. The purpose of this company was bold; to construct a traction railroad from tide level to the summit of a peak not two miles off and nearly half a mile high appeared visionary, if not impossible, to many. But with persevering skill a road was located upon a line 8.19 miles long, having an average grade of 5½ per cent. and maximum grades of 7 per cent., and overcoming 2353 feet elevation in this distance. Four and nine-tenths miles are curved, the minimum radius being 70 feet. Owing to the rough and ravine-cut topography, 25 trestles were necessary, the curvature and grade being maintained over these. In order to reduce



THROUGH REDWOOD GROVES AND OVER MOUNTAIN STREAMS.

the cost of grading and to develop sufficient length to overcome the elevation, the grade contour was followed as closely as possible. The very short radius employed permitted this to be done without tunnels and with but two through cuts.

The rails are steel, 57 pounds to the yard, laid to standard gage upon the ordinary redwood ties in use on the Pacific Coast. Grading, trestle work and laying cost about $55,000. The entire road cost $136,746.44, or practically $16,700 per mile.

The equipment consists of one 30-ton geared locomotive (Heisler), one 20-ton geared locomotive (Shay), six open canopy-top observation cars, one half-closed passenger car, and two flat cars. Cost of equipment, $22,450.*

The locomotives and cars are very thoroughly provided with brakes. First, the Westinghouse automatic air brake; second, a water brake; and third, a powerful hand brake to each locomotive and car. The efficiency of this equipment is attested in the operation of the road without accident or injury of any kind. The locomotives are always operated on the lower end of trains, and the maximum speed allowed is eight miles per hour.

The ride up the winding canyons and through the superb scenery traversed by this road is a treat of which one never tires. The point of view, the direction, and the character of the landscape are continually charging. With no deep cuts, no tunnels, facing first one and then the other and finally all the points of the compass, sweeping around spurs, with distant views of land and sea, and near views of great beauty; then facing the steep sides of the mountain, its geology and flora afford interesting pictures; then over trestles with the branches of the bay, redwood, madrono, oak and manzanita just out of reach —all these form beauties and attractions possessed by no other road known to the writer. A faint idea of the appearance of the road and of the scenery may be had from the appended photographs.

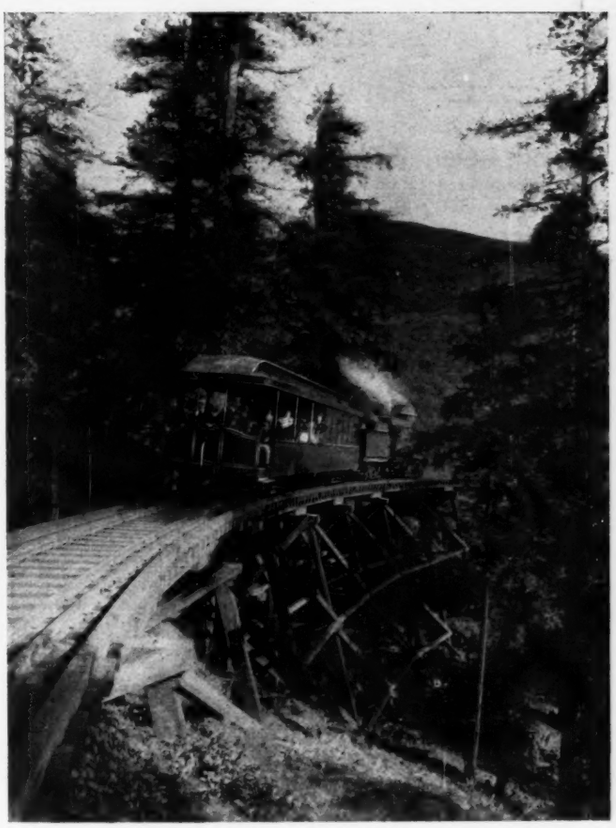
* * *

It is proposed to hold the Fourth Annual Convention of the Pacific Coast Electric Transmission Association at the Tavern of Mount Tamalpais, where special rates of $1.00 for the round trip from San Francisco have been secured. The session will begin Tuesday noon, June 19th, and continue through Wednesday. Papers of unusual technical and commercial value will be presented to the convention, and entertainment for Tuesday evening will be afforded in the usual banquet, to be followed by a descriptive lecture on electrical transmissions, which will be fully illustrated with stereopticon views.

It is recommended that members and visitors remain on the mountain over Tuesday night. The new Tavern will be finished just prior to the Convention and every comfort is assured; and the grandeur of the sunset and sunrise from the mountain is alone sufficient inducement to remain over night. Frequent train and ferry service to San Francisco, however, enable one to go and come at pleasure.

The secretary requests that all who intend to attend the Convention will promptly advise him of the fact that proper arrangements may be made in the matter of accomodations at the Tavern. Rates (special), $2.50 per day; with bath, $3.50. Address all communications to the Secretary at the offices of the Transmission Association, 238 Crocker Building, San Francisco.

*The writer is indebted to the officers of the Mill Valley and Mount Tamalpais Scenic Railway for the above accurate statistics.



THE ABORIGINES DIDN'T CLIMB TAMALPAIS THIS WAY.

LEAKAGE FROM HIGH VOLTAGE LINES.*

BY BUDD FRANKENFELD.

ALTHOUGH a three-phase circuit is more economical than either a single-phase or a two-phase line when considered solely from the standpoint of ohmic drop, this is not true when the working limit of voltage is approached, on account of leakage. The two-phase four-wire system inter-connected has six leakage paths, two at the limit of pressures and four at 70.7 per cent. of this pressure; the three-phase system has three leakage paths, each at the limit of pressure; the two-phase four-wire system with independent circuits has only two leakage paths, both at the limit of voltage, while the single-phase system has only one leakage path, namely, that at the limit of voltage.

Considering the various systems under this condition, the single-phase system shows the greatest advantage, the two-phase system with independent circuits coming next, and the two-phase inter-connected and three-phase systems being the worst and differing but little from each other.

*Abstract of paper read before the Chicago Electrical Association, April, 1900.

"I don't intend to get along without the JOURNAL," writes Edward P. Burch, late electrical engineer of the Twin City Rapid Transit Company of Minneapolis and St. Paul, and now a leading consulting engineer of the former city.

"The JOURNAL is neat and attractive and contains much that is of interest."—*Electrical Industries.*

Transmission

STANLEY INSTALLATIONS IN CANADA.

BY FRANK C. PERKINS.

THERE are three methods adopted at the present time in the transmission of power and electrical distribution that are worth considering. The first uses large electrical units in the center of a distribution of not very great extent; a moderate voltage being generated and distributed directly to the consumers

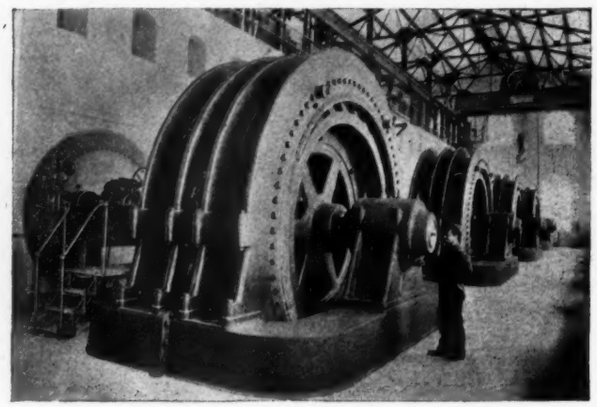


FIGURE 1.—FOUR 2000-KILOWATT, 12,000-VOLT, S. K. C. GENERATORS AT POWER HOUSE OF CHAMBLY MANUFACTURING COMPANY.

at approximately the voltage at which it is generated. In this case the machinery required for generation and distribution is simply one kilowatt of apparatus for each kilowatt delivered to the consumer, and the total efficiency of the installation may be as high as 90 per cent. Another application of this first method may be developed largely in the use of generators delivering high tension current from stationary armatures whence it is transmitted long distances and utilized. In the instances about to be described, power is obtained from synchronous motors without moving wire; *i. e.*: with stationary fields and stationary armatures, thus permitting the application of high-tension currents direct to the motor. This case will also allow of one kilowatt of generating and distributing apparatus for each kilowatt delivered to the consumer, and also an efficiency of, say, 90 per cent.

The second method involves the use of large high-tension units with stationary armatures, the transmission of power over the line from the machines direct and its reduction by step-down transformers, located at the receiving station, to a reasonable working

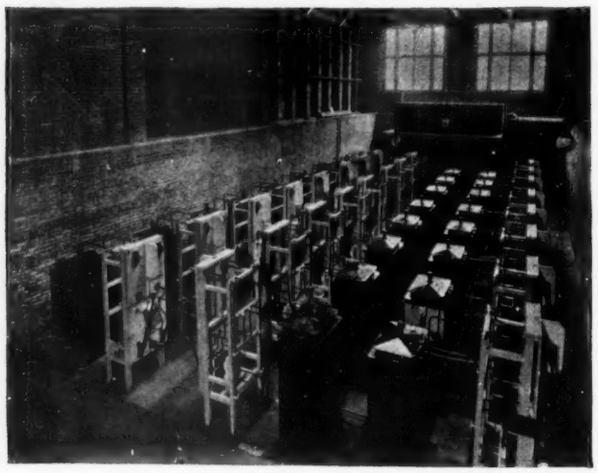


FIGURE 2.—STEP-DOWN STATION OF CHAMBLY MANUFACTURING COMPANY AT MONTREAL. 12,500 VOLTS TO 2200 VOLTS, TWO-PHASE.

potential. This method requires about double the apparatus necessary in the first case, the generating and distributing machinery amounting to two kilowatts of apparatus for each kilowatt delivered to the consumer, while the efficiency is reduced to, say, 85 per cent. There are many cases where this method is more advantageous than the one above described, while it is frequently found desirable to adopt still another method.

This third method necessitates the use of step-up transformers for raising the moderate voltage of the generators to the potential required for the transmission line. The use of step-up transformers at the power house and of step-down transformers at the substations, necessitates the purchasing of three kilowatts of generating and distributing apparatus for each kilowatt delivered to the consumer. Sometimes it is found necessary to utilize rotary transformers in addition, in which case the installation of four kilowatts in apparatus is required for each kilowatt delivered, in which event the efficiency is again reduced to about 80 per cent.

It will be of value to consider some noteworthy installations that are classed under one or the other of these headings.*

The four S. K. C. inductor-type generators shown in Figure 1 run at 153 revolutions per minute, and each has a capacity of 2000 kilowatts and generate direct a two-phase current at 12,000 volts. They are in operation at the power house of the Chambly Manufacturing Company, of Richelieu, Quebec, Canada, and the power is transmitted 17 miles to a sub-station in Montreal, shown in Figure 2, where two-phase static transformers reduce the line voltage from 12,000 volts to 2000 volts two-phase, the frequency being 8000 alternations per minute or 66 cycles. The base of one

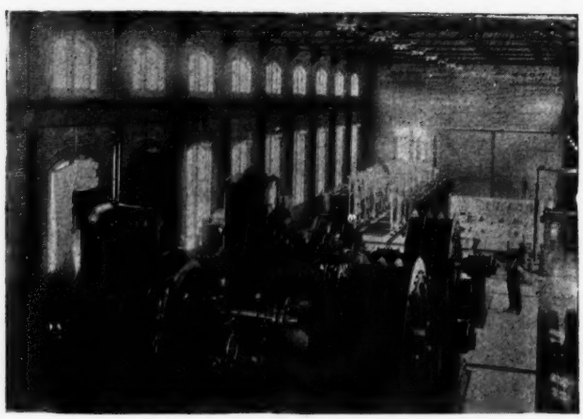


FIGURE 3.—1000-KILOWATT GENERATORS OF THE CATARACT POWER COMPANY, HAMILTON, ONTARIO.

of these generators is a hollow piece of iron of rectangular form and the outside dimensions are 17 feet long by about 11 feet wide by two feet thick, the weight being about 100 tons. It is set on a concrete bed, and the armature rests on the above base built up in two parts, bolted together. The field coil, which is also stationary, rests on the armature in a slot prepared for it, and is wound with bare copper strip insulated with japan and linen.

The inductor is built up of laminated iron and weighs about 30 tons. This is the only revolving part of the whole machine, the air gap being only one-half inch between the inductor and the armature. The field excitation is said to be less than one per cent. of the output of the machine. Turbine water wheels and electro-mechanical water-wheel governors are used. The turbines are 48 inches in diameter, and each pair of wheels, constituting one unit, develops 2648 horsepower at 153 revolutions under a 28-foot working head. The transmission is 16.6 miles long and the wires, four on each cross-arm, are of No. 00 bare copper 18 inches

*The principal transmissions herein referred to are more fully described in the following publications:

The Chambly Transmission, *Electrical World and Engineer*, Vol. XXXIV, page 999, December 30, 1899.

The Montmorency Transmission, *Cassier's Magazine*, Vol. X, page 3, May, 1896.—THE EDITOR.

FIGURE 4.—MONTMORENCY POWER HOUSE.

apart, fastened to triple-petticoat porcelain No. 1 "Imperial" insulators tested to 40,000 volts. The poles are white cedar and are 45 feet long and eight inches diameter at the top. They are set six feet in the ground and placed 90 feet apart. In some places it was found necessary to imbed them in concrete. The poles are protected against lightning by three barbed wires which are grounded at each pole throughout the entire length of the pole line. Two of these barbed wires are placed at the outer ends of the cross-arms and one at the top of the pole, while they are mounted on glass insulators. As the line pressure of 12,000 volts is applied direct from the generators, without any interposition of transformers, the installation thus far belongs to that classified under the first method.

However, in the sub-station at Montreal, shown in Figure 2, there are twenty-four 200-kilowatt single-phase Stanley transformers, in three rows of eight each. The coils in each transformer

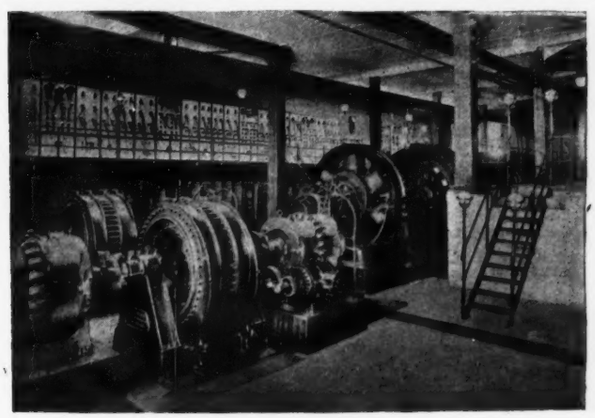


FIGURE 5.—QUEBEC RAILWAY, LIGHT AND POWER COMPANY'S PLANT

are immersed in mineral seal oil, and the transformers are water cooled. A rectangular cast-iron tank encloses each transformer, and free circulation is obtained through the coils of pipe, the water being obtained from the Lachine cahal near by. The switchboard for each static step-down transformer is placed directly in front of it as noted in the illustration. Obviously, the presence of step-down transformers reduces the installation to that described under the second method.

The installation of the Cataract Power Company, of Hamilton, Ontario, Canada, is of the type mentioned in method three. It is illustrated in Figure 3, wherein two 1000-kilowatt S. K. C. generators supply two-phase current at a frequency of 66 cycles to step-up transformers which raise the pressure to 20,000 volts. These transformers and switchboards for controlling the same are noted in the background. The transmission line is 34 miles in length.

In the power house of the Montmorency Electric Power Company, of Montmorency, Quebec, Canada, which is shown in Figure 4, are four 400-kilowatt generators, each of which is direct connected to its respective turbine. These generators supply two-phase current at 6600 volts direct to the transmission line which is seven miles long.

Reverting now to some of the uses to which electric power in large units is put, in the foreground of Figure 5 will be seen two 200-kilowatt alternating motors, each connected direct to two of the latest type of Brush arc lighting dynamos, for supplying current to the arc lamp circuits of the City of Quebec. This plant is equipped for lighting the city, supplying power to the various small users and for supplying current for operating the street railway lines. The plant is owned by the Quebec Railway, Light and Power Company. In the background of the illustration will be seen two 600-kilowatt S. K. C. motors driving the railway generators, while the switchboards are mounted on platforms on either side of the powerhouse.

In Figures 6 and 7 will be respectively seen a 450-horsepower, 2400-volt, two-phase synchronous motor operating a triplex pump

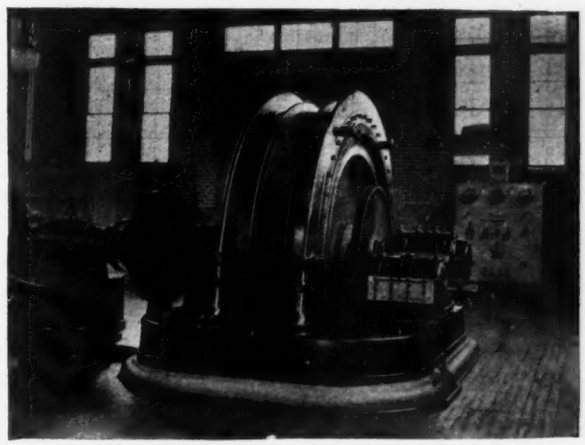


FIGURE 6.—450-HP. SYNCHRONOUS MOTOR OPERATING FROM 2400 VOLTS, TWO-PHASE, A PUMP, TRIPLEX, OF 5,000,000 GALLONS CAPACITY, AT ST. CUNEGONDE, QUEBEC.

having a daily capacity of 5,000,000 gallons. The motor is operated from the circuit of the Montreal Water and Power Company's plant at St. Cunegonde, Quebec. A good view of the gearing of the motor and pump may be had in Figure 7, while the exciter is belted from a pulley on the shaft as shown. The switchboard is shown in Figure 6; also the small starting motor, which is mounted on the same base and arranged to gear with the large motor.

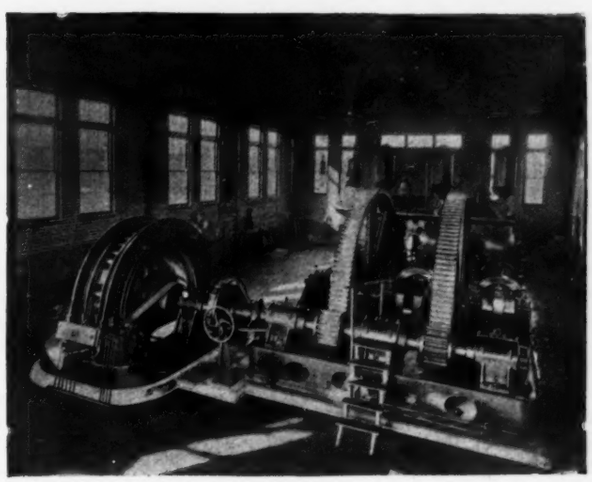


FIGURE 7.—GEARING OF PUMP AND MOTOR AT MONTREAL WATER AND POWER COMPANY'S PLANT.

Physics

THE RELATIONS BETWEEN ELECTRICITY AND ENGINEERING.*

BY SIR WILLIAM HENRY PREECE, K. C. B., F. R. S.

THE nineteenth century is distinguished in our profession chiefly by the knowledge we have obtained of the constitution of matter and of the qualities of the materials we utilize for the service of man, of the presence and characteristics of that medium—the æther—which fills all space, and of the existence, indestructibility, and protean character of that great natural source of force, motion, work and power which we call energy. Electricity is only one of many forms of this energy. It is measurable in well-defined and accurately-determined units. It is produced and sold, utilized and wasted. It is, therefore, something distinctly objective. It has even been defined by Act of Parliament.

There are four great principles underlying the practical applications of electricity: (I) the establishment of a magnetic field; (II) the establishment of an electric field; (III) the disturbance or undulation of the æther; (IV) the work done by the generation and maintenance of electric currents in material systems. It will smooth our journey over somewhat difficult ground if I commence by illustrating these principles with some elementary experiments.

THE DEFLECTION OF A NEEDLE.

1. A small magnet like that freely pivoted in the mariner's compass is always forced into a position at right angles to a conductor maintaining an electric current. I am using energy from coal burnt in the electricity works in Millbank street. It is brought into this building through conducting mains laid in pipes under the streets in its electrical form, and you see how its presence affects the needle. An electric current is not like currents of air, of water or of gas. They are due to the flow of liquid or gas, and each current is confined to the interior of the pipe conveying the material. The so-called electric current affects not only the conductor that directs it but all the surrounding space, including any matter that it contains, and especially the æther that fills it. You have here evidence of the existence of a magnetic field—a field of force, of strain and of motion. In fact, a condition of matter and the æther, and not a form of matter.

2. I take a portion of this conductor and wind it around a bar of soft iron. When the current is turned on, the iron is impressed with magnetism. We have made an electromagnet. Some of the energy of the electric current is transformed into its magnetic form, and we have powerful evidence of direction and stress—in fact, a magnified magnetic field.

3. We thus get attraction, repulsion, and we are able to produce rotation and to strike great blows.

4. I take two coils of insulated wire, one of which I superimpose upon the other. I send intermittent electric currents through the one and insert a telephone in the other. A loud sound is emitted by the telephone, which gradually dies away as I remove the coils away from each other. The sound is restored in its loudness as I approach the coils together again. Here we have evidence of ætheric disturbance. The electrical energy in the primary coil is transferred by waves through the æther and converted again into electric energy in the secondary coil, appealing in its sonorous form to our consciousness through the ears.

5. This ætheric disturbance is also the accompaniment of sparks in air. The sudden rupture of an air-gap, the conversion of the air into a conductor, its immediate restoration to an insulator again, give sudden periodic undulations to the æther, which, owing to its inertia, set waves in motion that extend to unknown distances. There is nothing but the air and the æther between me and that clock; yet I can control the movements of the clock by producing these sparks.

*The "James Forrest" Lecture, delivered before the Institution of Civil Engineers, London.

When I direct an electric current through acidulated water, the current breaks up the water into its constituent elements, oxygen and hydrogen; and if I insert a bar of white aluminum into a bath of blue sulphate of copper it is coated with a thin layer of brown copper. The electrical energy does work upon the water and upon the copper solution, and we have ocular demonstration of the mechanical operations effected.

7. The work done by an electric current upon matter is still further shown by this platinum wire, which I can first make hot, then incandesce to redness, and finally fuse into drops with the evolution of brilliant white light.

We thus perceive that electricity is purely mechanical in its effects. It requires matter to render it evident to the senses. Its transference is characterized by motion, chiefly undulatory when we consider the æther, but partaking of the most known forms when considering conductors and insulators. It is, therefore, essentially a dynamical agent in the hands of the engineer to carry out his duties.

THE APPLICATION OF FORCE.

Electricity enables the engineer to direct energy to great distances, and there to apply force at his will. Force is that which produces, or tends to produce, motion. It is the function of the engineer to utilize this motion. An electric current is by no means so simple a phenomenon as its name implies. The term itself is a survival of exploded doctrines. It is not alone the conductor that has to be considered but the whole circuit, especially its insulating portion, or dielectric, and the surrounding medium—the æther. The earth also frequently plays a very important and essential part. Moreover, the energy takes both the electric and magnetic forms, and one or other is dominant whenever the current is rising or falling or persistent. The rise and fall of lines of electric force produce a magnetic field and *vice versa*, the rise and fall of lines of magnetic force produce an electric field. In my experiments I converted this theatre into an electric and magnetic field, and if you possessed an electric sense you would have been conscious of unwonted disturbances. An electric field is that portion of space which is characterized by the presence of lines of electric force; a magnetic field by lines of magnetic force. Each line indicates the direction of stress, and the number of lines passing through unit area (one square inch or centimetre) the intensity of the stress. Matter through which they pass is in a state of strain; in conductors they produce currents; dielectrics are displaced electrostatically; magnetic substances, iron, nickel and cobalt, are polarized electro-magnetically. The motion produced is molecular motion—rotation, revolution, or oscillation. Lord Kelvin has very recently shown that an electrified body is set into rotation in one direction if positively excited, and in the other direction if negatively excited by the generation of a magnetic field around it, and that it will remain in rotation in virtue of its inertia during the existence of the field. When the current is alternating, it is always either rising or falling and changing its direction. The behavior of alternating is more complicated than that of continuous currents, but each are subject to well-known conditions and to simple mathematical treatment. Each has its own particular sphere of usefulness. Some of the energy is wasted in the form of heat in the conductor, in the dielectric and in the iron; some in the neighboring conducting mains, and some is conveyed away—dissipated in limitless space. The ratio of the useful energy to that which is generated is known as the efficiency of the system. The steam engine utilizes only 15 per cent. of the energy of the coal, the gas engine utilizes 25 per cent. of the same energy, a turbine can utilize 80 per cent. of the energy of falling water, but the efficiency of a dynamo has reached the high figure of 98 per cent. Alternating currents differ in their frequency. Those generated at Niagara pass through each cycle 25 times per second. The favorite frequency in the United Kingdom is 50, but many installations in the United States reach as high as 130. These frequencies in closed circuits can, however, be increased to millions per second in open circuits. In fact, Maxwell proved the identity of electricity and light by showing that they moved through the

æther with the same velocity — 196,400 miles per second — and in the same undulatory fashion. If the alternations could be generated with a frequency of fifty billions of waves per second, we should see electric waves as light rays. Electric waves and light waves differ only in their length. Hertz detected and measured these electric waves. Attempts have been made to utilize them, but so far not with much practical success. Whenever a conductor is forced through a fixed magnetic field so as to cut transversely the lines of force of that field, an electromotive force is set up in that conductor which varies with the length of the conductor, the number of lines cut by it, and the rate at which they are cut. This is the principle of the dynamo. Work is done upon the conductor in moving it against the resistance of the field. Energy is thus transformed from its mechanical to its electrical form. At Niagara 5000 horsepower are converted by one machine into electric currents of 1500 amperes driven by 2200 volts. If a conductor itself be free to move, and a magnetic field be projected through it while it is maintaining a current, it is forced into motion, and it becomes a rotating machine or motor. The electric energy of the current is transformed into its mechanical form. Its torque, or turning moment, depends upon the intensity of the magnetic field, on the length of the conductor, and on the strength of the current. This reversibility of the dynamo is of immense commercial value. Maxwell said it was the greatest invention of the century. Tram-cars in our streets, trains on our railways, tools in our shops and mills in our factories are thus worked by electricity. Dynamos and motors are subject to laws and conditions so thoroughly well known that exactness is assured and waste reduced to a minimum. There is no more perfect machine than a dynamo. Motors are nearly as good. Electricity as a science is fascinating to everyone, but it is deeply fascinating to the engineer. The reliability of its laws, the accuracy of its measurements, and the completeness and definiteness of the units to which its measurements are referred, give him confidence in his estimates and a certainty of the performance of his preconcerted operations. It places in his hands the means of directing the energy out of sight in positions known only to himself, and of applying it with great efficiency at the exact spot desired. No magician or poet ever conceived so potent a power within the easy reach of man.

THE DOING OF WORK.

The maintenance of an electric current through a conductor means the expenditure of work upon that conductor, and this expenditure of internal work means molecular motion. In solid conductors the result is heat. If the current be gradually increased, this motion is similarly increased. The result is successively incandescence, white heat, fusion and disruption. In liquid conductors the motion probably becomes revolution. The result is decomposition by the activity of the centrifugal force overcoming chemical affinity. The atoms fly away in fixed determined lines, and collect at opposite poles. In gases the transference of electric energy in the form of sparks means disassociation. Compound gases are broken up into their component elements under the same directing influences. Work is done upon the gas as in the previous instances. Joule established the law of the relations of current and heat upon a definite and accurate basis. Faraday developed the laws of electro-chemistry with equal exactitude. Prof. J. J. Thomson has determined the action of currents on gases. The principle of work that lies at the very root of the profession of the engineer enables all these operations to be measured in definite mechanical units, reducible to the common English standard, the foot-pound, but which the electrical engineer, with greater precision, refers to the scientific unit of work — the joule.

PURIFICATION OF MATTER.

The elements and their useful compounds are rarely, if ever, found pure. Impurities have to sifted away. Ores, raw produce, rocks and earths have to be subjected to various processes of refining and conversion to extract from them that which is wanted. The electric current by the above operations has proved to be a powerful agent to break up crude materials into their useful and useless constituents. The electo-chemical industries of the world are very extensive. According to Prof. Borchers, the eminent electro-metallurgist, the world manufacture of calcium carbide for the production of acetylene gas is utilizing a power equal to 180,000 horsepower; that of the alkalies and the combinations of chlorine for bleaching, 56,000 horsepower; of aluminum, 27,000 horsepower; of copper, 11,000 horsepower; of carborundum, 2600 horsepower, and of gold, 455 horsepower.

Electroplating is one of the staple manufactures of Sheffield and of Birmingham. There are nearly 200 firms working at the former place and over 100 at the latter. The decomposing bath and the arc furnace are revolutionizing many industries. Phosphorus is now being produced in England in large quantities from corundum, and aluminum from bauxite is extending in use and being reduced in price. The Postoffice is using aluminum for telephone circuits. I have recommended its use on a very large scale in the interior of Africa, where transportation is so costly. We can get the same conductivity as with copper with half the weight, and at a less price, and we can put up a line telegraphically ten times better than of iron for less money.

THE ANNIHILATION OF SPACE.

The elements of Volta and the battery of Galvani—zinc, copper, and a soultion of sulphuric acid — gave a convenient generator of electric currents which could be directed along wires to great distances, and thus, by establishing magnetic fields, could deflect needles in such a way as to form the alphabet and so transmit words and, therefore, thought. In wires of great length, while the initial speed is that of light, it takes time for the electric waves to rise and fall, so that the number of currents which can be sent per second is limited. Between London and Liverpool the speed of speaking is virtually unlimited, but between Ireland and America it is restricted by the so-called capacity of the cable submerged in the ocean. This capacity absorbs energy and retards the rate of rise and fall of currents. While a thousand currents per second can be sent in the former case, only six per second are available in the latter. Nevertheless, sitting on the shore of the Atlantic in Ireland, one can manipulate a magnetic field in Newfoundland so as to record simultaneously on paper in conventional characters slowly-written words. Thus we have bridged the ocean and annihilated space. We do this on a smaller scale in our own domestic circles when we press a button and ring a bell in our servants' quarters. The sound of a bell and the drop of an indicator is a message, "You are wanted in the drawing-room." When the button is supplemented by the telephone, as it is in so many houses now, you can speak your message, "We want coals," and thus the servant is saved two journeys, and you have gained some time.

Telegraphy is thus established in our homes. It becomes part of our daily life, not only in our domestic circles, but in our urban requirements and in our business relations. Not only is speech reproduced, but handwriting also. Town is connected with town and nation with nation. London and Paris, Paris and Berlin, Berlin and Vienna, speak to each other with clearness and distinctness in ordinary language. The scattered British empire is linked together. London and New Zealand are in communication with each other. All the world is joined in one unbroken whole, and we read on our breakfast-tables every morning the events of history made yesterday and the present condition of our friends in every quarter of the world. The regulation of the ever-growing traffic on our railways and the safety of passengers is secured by similar means. The telegraph not only places the manager of the line in communication with every station upon his system, but electric signals control the motion of every train. Trains are kept apart by a considerable space. Collision would be impossible were the human will infallible; but the world is made up very much of fools and temporary maniacs. We all do at times what we ought not to do. The annual return of violent deaths is an interesting document. When in England alone 138 persons choke themselves at their own tables, and 765 die by falling down stairs, we must not condemn the railway signalman,

who is responsible for the death of only 58 in 1898. A railway signal-box is an electrical exhibition. Every line is protected by its own electric signal. Every distant outdoor mechanical signal is repeated back. The danger signal is locked and cannot be lowered to "line clear" until it is unlocked by the train itself or by the distant signalman. F. W. Webb (member of council) is not only working the outdoor signals the nselves by electrical energy, but he is moving the points and switches by the same means. So far, the experience gained at Crewe during a period of about twelve months, from the working of a signal cabin containing about 60 levers, has been such as to justify confidence and the extension of the system, and some ten cabins, containing about 1000 levers, will be provided.

The apparatus has been designed to work in with, as far as possible, the standard signaling apparatus of the London and Northwestern Railway. The interlocking frame may be said to be the ordinary mechanical frame in miniature, occupying one-third of the space. The levers — about six inches in length — are placed in two tiers, and are manipulated in the same way as the levers of a mechanical frame, consequently the signalman accustomed to the old type has nothing to learn in the new. The levers are mechanically locked by means of tappet locking, and they control carbon switches by which the 110-volt electric current is transmitted to the motors. The object of this electric working is primarily to reduce the manual labor of the signalman and enable him to pay more attention to the movements outside his cabin; increased speed of working; the remaval of obstructions on the ground caused by the numerous wire and rod connections necessitated by the present system; and finally, a reduction in the number of signalmen employed.

Thus electricity adds to the security of life. It supplies the railway man with a new sense and the engineer with a new power. The abridgment of time necessarily follows from the annihilation of space, but the chief element which saves our time so much is the fact that we can, by electricity, do so much more from one spot. Indeed, in the United States the railway companies complained that their revenue between New York and Chicago suffered through the introduction of the telephone. People remained at home and did their business by wire. It is very curious when visiting the United States to find that their morning papers contain extracts from our London evening papers of the same day. One frequently receives messages in England that were sent off tomorrow. This is due to the difference of longitude. Wireless telegraphy, or, as it is better termed, ætheric telegraphy, has made but small progress, owing to the simple fact that the demands for its services are so very few. There is no commercial business in it.

The fascination of electricity and the sensation of breaking down space by apparent magical means, have led to much gratuitous advertisement on the part of the press. I wrote in 1888: "The influence which electric currents exert on neighboring wires extends to enormous distances, and communications between trains and ships in motion, between armies inside and outside besieged cities, between islands and the mainland, has become possible without the aid of wires at all by the induction which is exerted through space itself." The Postoffice has for sixteen years been developing this system. Several extensions are now in hand.

TRANSMISSION OF POWER.

The property that an electric current possesses of converting its environment into a magnetic field, and the fact that the projection of a magnetic field through a conductor induces an electric current in that conductor, are profilic of many valuable instruments by which we tranform energy into different intensities, and thus economize the cost of its transmission. The pressure that drives the energy through a circuit is called the voltage, the electrical form which this energy takes is sometimes called the amperage, and the resistance which the conducting part of the circuit offers to this flow of energy may be called the ohmage. There are other conditions that lead to waste, but these three conditions effect utility. The amperage by Ohm's law depends simply on the voltage and the ohmage, and the product of the amperage and the voltage, by Joule's law, gives the wattage, or the rate of expending energy, usually called power. The higher the voltage the smaller the amperage, and hence the less the weight of copper needed.

The present practical limit of voltage along aerial conductors appears to be 40,000 volts. Beyond this pressure the dielectric strength of air breaks down. Higher voltages are practical in insulated mains, but their expense is a ban to their use. It is not considered advisable to construct dynamos giving higher voltages than 2500 volts, although in many cases 5000 volts are produced; but these high voltages are easily and safely converted by transformers to any other higher pressures. If C be an iron case made up of the thinnest and softest procurable iron sheet, and it be surrounded first by a primary wire maintaining the alternating currents at 5000 volts; then if S be a secondary wire, having eight times the number of turns around the iron core that the primary wire has, then the voltage in the secondary circuit will be about 40,000 volts, setting up alternating currents of the same frequency but of one-eighth the amperage. It would be exactly one-eighth if there were no waste of energy; but there is waste in the iron, the copper and the air. Still, the efficiency is very high, and frequently reaches 90 per cent.

Energy is also transformed in its continuous form by rotary converters, but in this case the process is usually the reverse. Direct continuous currents of 100 amperes and 3000 volts are reduced to 500 volts by acting as motors to rotate generators, giving 600 amperes for, say, tramway working. Again, at Tivoli, 18 miles from Rome, the energy of the falling water there is transmitted to Rome in the form of alternating currents at 6000 volts, and is there converted by rotary transformers into direct currents at lower voltages for battery, traction and motive purposes.

The sun is the *fons et origo* of all the available energy upon the surface of the earth. Coal and oil are extracted from its crust; oxygen is found in its atmosphere. Grasses, corn, fruits and vegetables become food and fuel for beast and man. Waters are converted into vapor, forming clouds, rain, brooks, rivers, torrents and falls. The atmosphere is disturbed by wind, and the waters of the ocean by tides. Energy is thus found available for useful work in many different forms. The problem before the engineer is how to select the best form of energy for his purpose, and how to utilize these waste energies of nature so as to secure the best economical result. Falling water can, by a turbine or impulse wheel, convert the energy it possesses in virtue of its fall into the form of electricity. By the aid of transformers it can be raised to very high voltages; 40,000 volts is employed in California,* 11,000 in Niagara. We use 10,000 between Deptford and Trafalgar Square. It can thus be transmitted to any reasonable distance, and there it can be utilized to do useful work. The waste forces of nature are thus within our reach. The waterfalls of the Highlands may work the tramways of Glasgow; Niagara already works those of Buffalo. The economy of this system for large industries is a question of the relative cost of the generation of energy by other means. Energy on the coalfields can be produced cheaper by burning coal than by any water scheme I have yet examined in this country. The price and abundance of coal renders the transmission of energy to great distances at present a very limited question indeed. Where coal is scarce and dear and water abundant, as in Switzerland, water power is very much utilized. Where coal is abundant and cheap, as in England, it is uneconomical to adopt it. The transmission of power within limited areas by electricity in our cities, is now within the range of practice. In Edinburgh it is supplied at the rate of 1¼d. per unit; this is 0.83d. per horsepower-hour. It is invaluable in small industries. It is there ready to be used when it is wanted; it wastes nothing while idle. The economy and efficiency of distributing power over mills, factories and workshops by electricity instead of by shafting, gearing

*40,000 volts is used in the Provo-Mercur transmission in Utah. The highest transmission voltage used in California is 33,000 volts, as used by the Southern California Power Company in its 82-mile line from Santa Ana Canyon to Los Angeles. The new Blue Lakes-San Francisco transmission of 145 miles is to be operated at 60,000 volts.—THE EDITOR.

and belts, is so pronounced that the change is being effected in every country with great rapidity. If it were a question of the mere efficiency of the two systems, the advantage of the change would not be so obvious; but it shown by the horsepower-hours expended, which means the coal bill. The efficiency of an electrical system is rarely less than 75 per cent., while that of shafting is frequently as low as 25 per cent.; but the economy is the continuous waste of the latter that tells on the coal bill, while in the electrical system there is no such waste. The motor runs when it is wanted, and expends only what energy is wanted for the particular work to be done. Electrical measurements are so exact and so easily applied that automatic records can be obtained of the work done by each machine. Every up-to-date shop should have its electric plant for healthy light, cheap power and handy distribution of material. Its economy is demonstrable in the smallest, but in the largest shops it is at once most marked. It is always available and it costs little. Ignorance or timidity restricts its use very much. The number of works that are run by electric motors in different parts of the country is very large indeed. The efficiency, handiness and economy of doing so is so marked that the practice is extending with great rapidity. Motors themselves are being daily improved.

We underrate very much the progress made in the United Kingdom in different industries, owing to the secretiveness of the British manufacturer. He will not report what he is doing in the press, and the press leaves him severely alone. Electricity as an economizer, by increasing the speed of output and by reducing waste, is as much at the disposal of the British as of the American manufacturer. But John Bull clings with affectionate and conservative fervor to the capital expended by his grandfather, while Uncle Sam does not hesitate to chuck obsolete plants on the scrap heap, if, by doing so, he can increase his business. Progress in the States is also not so seriously checked by trades unionism as it is here. I am told that the Bricklayers' Union in England limits a man's daily work to laying 400 bricks, while in the States he does 1200! This limiting of the output of labor is a much more serious tax on the nation than a war tax. It drives trade out of the country, it restricts the intelligence and lowers the tone of morality of our working classes. It is a disease to be grappled with.

On the Clyde and the Tyne, and, indeed, wherever shipbuilding is flourishing, there we find electrical energy driving machine tools, holding up plates, and assisting in various processes. In many large machine works cranes and travelers are moved by it. At Boston, U. S. A., crossing the Charles River and uniting Charlestown, the scene of the famous battle of Bunker Hill, with its headquarters, is a new bridge 100 feet wide and 1920 feet long, having a draw of 240 feet span, weighing 1200 tons. This draw is opened and closed by electric motors. In the Postoffice we have introduced electric motors very largely. At Leeds they are used for driving pneumatic pressure and vacuum pumps, employed there to work the pneumatic tube system. They are also used for working automatic stokers, ventilating fans and lifts.

TRACTION.

It is for traction purposes that electricity is making gigantic strides. In the United States tramway working by its means has become practically universal. In the United Kingdom it is making rapid way, and in connection with electric lighting it is giving great economical results. The combination of the two systems is most effective. In St. Helens, in Lancashire, where 13,435 eight-candlepower lamps are connected, and a small tramway system of nine cars simultaneously running, is at work, the works costs have been brought down from 3.23d. per unit to 0.67d. per unit. The price for electric light has been reduced from 6d. to 4½d. per unit, and it will probably be lowered to 3½d. This is after only eight and a half months' working. St. Helens is an object lesson to all municipalities, especially to Glasgow, where a very false start has been made. Electric railways are also growing apace. A bold attempt is being made by the Metropolitan Railways to work the existing line in such a way as not to interfere with the existing traffic or even with the permanent way. A new train of six coaches weighing 180 tons, having a motor car at each end weighing 54 tons, is about to run between Earl's Court and High street, Kensington. Each motor car is mounted on bogies, and each bogie has two electric motors, so that there are eight driving-wheels, each bearing 6.75 tons. The driving-wheels have diameters of 47 inches. The length of the train is 240 feet. Each motor is rated at 200 horsepower, or a total of 800 horsepower for each motor car. But there is a wide margin, and we have already applied 950 horsepower in starting a load of 270 tons on the incline of 1 in 43. Electric traction has an immense advantage over steam traction in impressing a continuous and uniform torque or turning moment on the shaft, and consequently a continuous and uniform effort on the trend of the wheel. The action of the steam locomotive is intermittent and the bite not continuous, hence such frequent slipping on greasy rails. Again, the maximum torque can at once be applied by the current, and, in combination with the constant effort, it increases the acceleration so that a train acquires its maximum speed much more quickly. We shall increase the mean speed of the Metropolitan trains from 11 miles per hour to 15, and thereby increase the capacity of the line over 30 per cent. The stoppages on the underground railway are so frequent that the trains are always either accelerating or stopping. They never reach their top speed as they do on main lines. Electric traction enables them to start quicker and start more promptly. On the Metropolitan the 180-ton train acquired 20 miles an hour in 200 feet, and when going at the same speed it was stopped in 130 feet — half its length. Smart work on such a railway depends on the rate at which trains can be emptied and filled. The English system of compartments and side doors facilitates this. It would be still further expedited if we could have one platform for entry and one for exit, and one class only.

The Liverpool and Manchester Lightning Express Railway, promoted by a very powerful representative syndicate of those two great commercial centers to carry out the scheme of Mr. Behr, is a very bold and promising venture. The line is to be monorail, 34 miles long, direct between the two cities, without any intermediate station and with no crossing. There are to be cars every ten minutes. The speed is to be 100 miles per hour, and the time of transit 20 minutes. I know of no reason why this should not be done with safety and comfort.

The automobile car of the future has not yet seen the light. It will be electrical. Immense progress has been made in motors and in batteries. Lundell has shown how to store up the energy now wasted in descending hills, and to recover some of that absorbed by the inertia of the car. Although a battery has already been able to drive a car 100 miles with one charge, we are waiting patiently for the real automotor storage cell.

ELECTRICITY IN WAR.

A strong contingent of electrical engineers has volunteered for service in South Africa. They are all scientifically-trained, practical young engineers. Bicycles, field telegraphs, telephones, arc and incandescent lamps, cables, searchlights, traction engines and generating plant will be under their care. They are under the command of Major Crompton, a member of the Institution and an old soldier. Electricity has been extensively applied to the development and utilization of explosives in both the civil and military divisions of our profession. Charges are safely fired under water and blasted in mining and demolition operations by small exploding dynamos, magnetic-electric machines or induction coils acting upon high-tension fuses. Our honorary member, Sir Frederick Abel, has specially distinguished himself in this direction. His fuse, composed of phosphoride and subsulphide of copper, is universally used by our War Department. Time guns are thus fired at stated hours at different sea-ports by currents originating in Greenwich Observatory. Broadsides in battleships and guns in turrets are similarly discharged. Torpedoes are even directed by currents from the shore. The defence of our coasts by submarine mines and their explosion by currents when the

(Continued on page 107.)

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EDITORIAL.

GAS-DRIVEN CENTRAL STATIONS.

It is probable that the next marked reduction in the cost of producing power will be brought about through the utilization of gas engines in large units operated by fuel gas, whence electrical power will be distributed for all industrial purposes except, possibly, in cases where large blocks of power are desired, and wherein gas transmission and conversion into power may be found to be of greater economy. The present tendency in electrical engineering practice is to remove the generating station to a site where water for condensing purposes may be available, whence service is delivered through high-tension transmission and a more or less complicated system of distribution. Without doubt the successful development of gas engines in large units, say of 1000 horsepower or 1500 horsepower, as may soon be expected, will tend to cause engineers to revert to the earlier practices of locating the central station at some point that will be as near as possible to the center of a low-tension distribution. It is perfectly proper to erect the producer gas works at a remote point where real estate is cheap and where coal may be had at the lowest cost; and it is also perfectly proper to take the central station back to the site where it will be in the most busy and populous portion of the city, provided the plant be driven by gas engines that are in turn supplied with gas by an independent pipe line from a gas plant that is favorably located at some distance, say on the water front, where costs are a minimum. Putting aside any question as to the part which long distance electrical transmission will take in shaping the power industry, it seems conclusive that the marked superiority in the efficiency of gas engine processes over those of the steam engine gives fullest warrant for the upholding of these views.

These ideas possess neither the features of newness nor of novelty, particularly in European practice, and it is probable that they would have taken tangible shape in the form of actual installation in this country some time since had it not been that Americans have been backward indeed in their development of the gas engine and the gas engine industry. Now, however, there seems to have been an awakening to the importance of the matter and it need not occasion surprise if, after the new lighting and power plants now being built in and towards San Francisco are in operation, this city will become possessed of a gas engine station that will be representative of the most recent gas engineering practice. Then will be witnessed a battle royal between all that is the latest and best in steam, gas and electrical transmission engineering.

Of these three lines of engineering, it is evident that that pertaining to gas is the least thought of by those who are managing the affairs of lighting, heating and power corporations. This is not as it should be, or rather the electric central station manager should not lose sight of the fact that in the gas business, in which rests his quondam enemy, is to be found his strongest ally.

Why? Because it is inherent to his business that he should furnish light, heat and power—that triune commodity which he is so prone to divide into three separate headings, each divorced from the other, or from which he is, at best, so apt to drop entirely the factor of heat; because it is to his best interest to furnish light in whatever form the public may demand; because there are no known means which compare with those possessed by gas for the distribution of heat over large areas; because the efficiency of the gas engine discounts that of the steam engine, and because, moreover, modern engineering inclines to the conviction that during the coming decade higher attainments in efficiency will be reached by the use of the gas engine utilizing fuel gas than by any other means.

It has long been a marvel to many why isolated plants are able to produce electricity for consumption in individual buildings or blocks at a cost much below that which central stations are able to furnish it, and it has remained for Alton D. Adams to state succinctly* why the chief reason therefor rests primarily in the fact that the isolated plant takes full cognizance of the value of the heat in the engine exhausts and applies it to a useful purpose. Starting with the central station which derives all of its energy from coal, it appears that with the best possible steam and electric equipment, operating under ideal conditions as to amount and uniformity of load, only about eleven per cent. of the energy of the coal is delivered as electric current at the dynamo terminals, all the remainder escaping as useless heat. Allowing for the additional losses in practical operation, due to partial and fluctuating loads, storage batteries and transmission lines, the actual delivery of energy to customers can hardly exceed nine or ten per cent. of that derived from the fuel. On the other hand, an isolated plant with first-class boilers and an economizer generates steam containing 75 per cent. of the total heat from the combustion of coal, practically all of which, in one form or another, is available and made to pay as

*Cassier's Magazine, Vol. XVIII, page 54 *et seq.*, May, 1900.

energy consumed in the maintenance of lighting and heating service. It is thus that, during say six months of the year, the efficiency of the isolated plant is some seven times greater than that of the central station.

In order that many large and desirable loads now operated in some cities by private lighting plants may be shifted to the public supply, it is necessary, not only that the rates of electric energy for light and power be lowered, but also that central stations distribute heat at a less cost to consumers than that at which they can produce it. It seems to be obvious that something is very radically wrong in central-station practice when it countenances for year after year, the distribution of only one-seventh as much of the energy of the combustion of coal as the isolated plant is able to secure.

If, then, central stations are to secure the light, heat and power loads of large buildings, they must find a way to distribute a much larger percentage of the energy from the combustion of coal than is now common. It is not difficult to show where central stations suffer their most serious losses of energy. The best boiler plants generate steam that contains about 80 per cent. of the heat energy of the coal burned; and large electric generators deliver as electric current the equivalent of 90 per cent. of the mechanical energy supplied to them. In contrast to these high efficiencies, the steam engine changes at best about 15 per cent. of the heat in the steam entering its cylinders into motion at the shaft. Of the heat contained in the steam leaving the boiler, 85 per cent. is thus lost in the engine exhaust, and this amounts to $0.85 \times 0.80 = 68$ per cent. of the total heat developed by the combustion of coal. It is at once clear that if steam-driven electric central stations are to secure the large light, heat and power loads that seem to properly belong to them, this great portion of the energy of coal in engine exhaust must be gathered up and delivered to consumers instead of idly going to waste as at present. When viewed in this light it must be confessed that the present tendency of engineers to remove power plants away from the centers of population to distant locations where coal and real estate are cheaper and where engine economy may be increased a few per cent. by the presence of condensing water, savors too strongly of saving at the spigot to be perpetuated in engineering practice.

If steam-driven central stations are to utilize and turn to good account the enormous values that are wasted in their engine exhausts, as indeed they must do before they attain their highest efficiency in operation, they must come back to the centers of population with boilers, engines, condensers, generators, storage batteries and innumerable auxiliaries, or otherwise the distribution of the heat in exhaust steam is impossible.

In this dilemma, let us again turn to gas engineering. The steam engine must be quite close to its boiler if economy in operation is to be secured, but gas engines may be located many miles, if necessary, from the plants where gas is produced for their operation, without serious effect on the economy of power production. Electric generating stations driven by gas engines are especially suited to crowded areas by reason of the relatively small amount of room they require. The problem of transportation of coal and ashes is absent with them, and the only water required is that for cooling the cylinders of the engines, this water being cooled and subject to loss only by evaporation. Owing to the ease with which gas is transmitted through pipes, the plant for its production may, as before stated, be located where all of the possible economies as to transportation, water and labor of operation may be practiced, and such a plant may supply gas-driven electric generating stations over a very large area. The efficiency of gas engines, which ranges from 20 per cent. in small engines to 25 per cent. in large ones, allows a delivery of from one-third to two-thirds more electric energy for the same coal consumption than does the steam engine with its efficiency of a paltry 15 per cent. Having made this positive gain of efficiency in the production of electric energy, the gas engine delivers the remaining heat from its internal combustion in a form that can be utilized. For gas engines of medium sizes the distribution of heat may be fairly taken as: delivered to work, 20 per cent.; conduction and radiation, 10 per cent.; jacket water, 40 per cent., and exhaust gases 30 per cent. of the total heat produced by the gas consumed.

The temperature of the jacket water may be taken to be about 150° F., and that of the exhaust gases 700° F. These hot gases can be readily used to raise the temperature of the water from the cylinder jacket to 212° or even higher, and thus fit the water for heating purposes as well as can be done with exhaust steam. This hot water may be pumped through a system of hot water mains for general heating purposes, the return flow passing through the cylinder jacket again and the coils exposed to the hot gases. With gas that contains 80 per cent. of the energy of the coal, the jacket water and exhaust gases just named contained $0.80 \times (30 + 40) = 56$ per cent. of the heat of the coal, or about ten per cent. less than exhaust steam.

The conclusion seems irresistible, then, that gas engines and producers, in connection with electrical supply, not only increase the percentage of fuel energy delivered at the dynamo terminals over that possible with steam, but greatly facilitate the location of electric generating stations to such points as will enable the commercial distribution of more than half the heat of the coal.

There appears in another column of this issue, an abstract of a lecture recently delivered by Prof. Vivian B. Lewes before the Incorporated Institution of Gas Engineers, London, which is timely in that it deals with a process of making a fuel gas that bids fair to become of great importance in the development and operation of gas-driven electric stations. This method is commonly known as the Dellwik or the Dellwik-Fleischer system, and it is distinctively a water gas process, to understand which it

should be borne in mind that all practical water-gas processes are intermittent, and consist in heating up the fuel by means of an air-blast, followed by the decomposition of steam by contact with the incandescent carbon thus heated. The older water-gas generators produce generator gas ($CO + N_2$) during the heating periods, which occupy about 45 minutes of each hour, leaving only 15 minutes for the water-gas production. The Dellwik-Fleisher water-gas generators are heated about 10 minutes, giving only waste gas ($CO_2 + N_2$), leaving 50 minutes of the hour for the water-gas production, so that the yield of gas is more than double that obtained by the older processes. Professor Lewes found by experiment that one ton of coke, containing 87.56 per cent., or 1961.8 pounds of carbon, yielded 77,241 cubic feet of Dellwik water gas, having a gross calorific value in Junker's calorimeter of 304 British thermal units per cubic foot. Hence the calorific value of this water gas from a ton of coke was over 82 per cent. of the heating value of the total coke used in both generator and steam boiler, taking 20 per cent. of the coke as used for raising steam. Every one pound of carbon yielded nearly 40 cubic feet of this water gas composed of 51 per cent. hydrogen, 41 per cent. carbonic oxide, 0.5 per cent. of marsh gas, 4.5 per cent. carbonic acid, and 3 per cent. nitrogen. During the last two years Dellwik water gas has been used in the iron industry for firing the welding furnaces, and for tempering and annealing. On the Continent this water-gas is also used to increase the capacity of coal-gas works. The mixture of coal gas and water gas is enriched by benzol to the desired candlepower. The supply of benzol is steadily increasing from by-product coke ovens, and at the present time benzol-carburetted water gas, as admixture to coal gas, is produced in Germany at a lower cost than is possible with water gas enriched by oil. As an enricher benzol is likely to supplant petroleum owing to the rise in the price of the latter.

Dellwik water gas is one of the cheapest fuels for producing power by means of gas engines. One large British gas engine firm is prepared to guarantee a consumption of 30.5 cubic feet of this water gas per horsepower-hour. It is said that with coke at 9s. ($2.16) per ton the gas costs only about 3d. (6 cents) per 1000 cubic feet, and this makes the cost per hour of a horsepower about $\frac{1}{10}$d. (2 mills) for fuel.

It is well for the electric station manager, whether he be interested in a steam, water power or electrical transmission plant, to be awake to the fact that progress is the watchword along every line of engineering as well as in that of his own domain, and that while electrical power transmission, for instance, has been making wonderful advances, the gas industry as well has been making equally marvelous strides.

THE UNION OF LIGHTING AND TRACTION.

The consolidation of public electric light and power plants with those now maintained exclusively for electric traction purposes is held by A. D. Adams, in an article in *Cassier's Magazine* for January (Vol. XVII, page 221), to be the next inevitable step in the march of power centralization. Electric traction plants have remained unique in their devotion to the single purpose of tram-car propulsion. It is true that a small amount of energy is diverted for heat and light in the cars and car-houses, and in some cases along the line of the railway, but the general practice has been to refrain from public light and power supply. Thus the design of electric traction plants for a single kind of service has resulted in marked uniformity in their equipments. In almost every case direct-current generators, operated in multiple and of about 500 volts pressure, constitute the entire dynamo plant.

In the more recent stations the generating equipment, like that in public light and power plants, has been reduced to the smallest practical number of large, direct-connected engines and dynamos. The several steam plants of moderate size formerly common in large traction systems, are now giving place to one large generating station, in each case supplemented with small sub-stations of storage batteries. Batteries also find a place at the main station for the same purposes as in light and power plants.

Most, if not all, of the advantages sought by the consolidation of several small generating plants into one large one and the substitution of a few large engines and dynamos for many of less capacity, may be greatly increased by the union of electric light and traction plants. The times of maximum evening loads in lighting and traction systems do not exactly coincide, so that the combination of these loads would materially extend the time during which the great bulk of station equipment could be in use each day. The large all-day and late-evening load of tram-cars would increase largely the ratio of the average, compared with the maximum load, in a combined lighting and traction plant, over that existing in a simple lighting station, and the economies incident to a few large, direct-connected generating units, as to fuel and labor, would be especially advanced in the combined plants.

Stations for combined electric light and traction service have thus far been inaugurated in but few instances, because it has seemed impractical to draw current from the same machinery for both services; but means and methods are now at hand by which either high or low pressure services for public lighting and power can be supplied by the same dynamos that operate the electric traction on either short or long distances.

STORAGE TRACTION ONCE MORE A FAILURE.

The Chicago Electric Traction Company, which operates the storage battery electric railway system widely known as the Chicago and Englewood line, has decided to abandon the use of storage batteries as a means of propelling its cars and to install instead an overhead trolley system. The storage battery system is being abandoned because of the mechanical difficulty attending the charging of batteries in cars on branch lines, because the weight of the cars affect the track to some extent, and because

the cost of operation is about one-half more expensive than with the overhead trolley.

And now, was there ever a single, solitary man abroad in the land who in any way, shape or manner ever referred to the Chicago-Englewood line as being even the suggestion of an instance demonstrating at once the truth of his contention that storage-battery traction was entirely successful, and that, therefore, the overhead trolley was altogether unnecessary?

REPREHENSIBLE, TO SAY THE LEAST.

The *Canadian Electrical News* has for its leading illustrated article for May a practically verbatim reprint of the description of the Mount Whitney transmission appearing in the JOURNAL for January last, with cuts and all.

This is perfectly agreeable to the JOURNAL which, in acknowledging the compliment, must—even though it be ungenerous—remind its contemporary that it has omitted to accredit both the authorship and the initial medium of publication of the article.

Gas

INDUSTRIAL GAS.—XIV.

BY FRANK H. BATES.

[THE OXYGEN CALORIMETER—CONTINUED.]

EXAMPLE illustrative of operation: The entire apparatus, including the calorimeter, filled with water, the oxygen tank with oxygen, etc., had been standing in the room sufficiently long to bring all to nearly a common temperature. A sample of the coal under test was selected with care that it represent an average, and finely pulverized.

One gram of the sample was placed in an air bath and subjected to a temperature of 215° F. for one hour, then removed and placed in a desiccator until cool, when it was weighed and the loss, representing moisture, ascertained.

A porcelain cup was now heated in the flame of a Bunsen burner to ignite any foreign matter adhering to it; should an asbestos crucible be employed especial care should be exercised to burn off all organic matter.

The cup was then weighed.

About one-half gram of the dried coal was now placed in the cup and the whole weighed.

The cup containing the coal was now placed within the igniter, the platinum wire dipped well into the coal and fastened by its two ends to the holder arm and conducting rod respectively.

The igniter was inserted into the combustion chamber of the calorimeter and made fast by the tightening-nut, and electric connections made up with the exception of one wire of which one end was left free for igniting.

Oxygen gas was admitted until the gage indicated a a pressure of 175 pounds, and notice was taken that no leakage occurred, the gage remaining constant.

The movable scale on the water column was adjusted so as to bring the zero graduation in line with the bottom of the meniscus formed at the surface of the water within the glass tube. Notice was taken that the water remained at this level.

With stop-watch in hand the coal was ignited by bringing the free end of the electric wire in contact with the body of the calorimeter, causing a momentary glowing of the incandescent lamps, their quick extinction indicating the fracture of the platinum wire. The time of ignition was noted.

The water in the glass tube began rising at ignition, shortly reaching a maximum height, when the time and scale reading were noted.

A time equal to that occupied in the ascension of the water was now allowed for the radiation factor, when the scale reading was again taken.

The gaseous products of combustion were allowed to escape from the combustion chamber by way of the oxygen valve.

The igniter was removed and the contents of the crucible showed but a slight residue together with ash.

The crucible, together with residue and ash was weighed, then ignited for some 15 minutes in the flame of a blast lamp, placed in the desiccator to cool, and then weighed, this weight giving the amount of residue or matter not burned in the calorimeter, which is considered as pure carbon.

The data is now complete and may be tabulated as in the following form:

DETERMINATION OF THE CALORIFIC POWER OF.....COAL

Date	*Locality*.....	*Notes:* Edgar's Oxygen
No. 1.....	.....	Calorimeter employed.

WEIGHTS:

Weight of crucible (porcelain cup).....	6.37	grams
" " and sample (coal).....	6.87	"
" " and contents after ignition in calorimeter	6.414	"
" " and contents after ignition in blast-lamp.....	6.4135	"
" sample (coal).....	0.500	"
" residue and non-combustibles.....	0.044	"
" residue.....	0.0005	"
" non-combustibles	0.0435	"
" combustibles....	0.4565	"
" sample (0.50 grams × 0.002205)	0.0011025	lbs.

SCALE READINGS:

First scale reading.....	0.0 inches	Time, 8h. 10′ 00″
Second " "	4.7 "	" 8h. 12′ 40″
Third " "	4.05 "	" 8h. 15′ 20″
Actual " " 4.7 — .0 = ...	4.7	inches
Cooling correction 4.7 — 4.05 = ...	0.65	"
Corrected reading.....	5.35	"

One inch of scale by calibration test equals 2.696715 British thermal units per pound of fuel burned. Hence

5.35 inches (corrected scale reading) multiplied by 2.696715 inches (scale constant) = 14.42742525 British thermal units per .0011025 pounds; or,

$$\frac{14.42742525 \text{ B. T. U.}}{.0011025 \text{ pounds}} = 13086.1 \text{ British thermal units per pound;}$$

and,

.0005 grams × 0.002205 = .0000011025 pounds,

.0000011025 pounds × 14544 (B. T. U. per pound of carbon) = .016035 B. T. U. correction for residue,

.13086.1 B. T. U. + .016035 B. T. U. = 13086.116035 B. T. U. per pound = total calorific power.

REMARKS:

The sample of coal was in this instance, previous to testing, dried of free moisture by subjecting to a temperature of 215° F. for one hour in an air bath; the loss by moisture being.....

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NOTE. The correction for the residue is given in the above case simply as illustrative of the method; it is generally, as in this instance, too small to be considered.

A constant which may be found for each particular instrument and which would shorten operations somewhat, would be a value representing the B. T. U. per pound per inch of scale for each gram of sample taken. In the above case this constant is 1223., and could be used as follows:

5.35 (corrected reading) × 1223 = 6543.05 B. T. U. per ½ pound since the sample taken weighed ½ gram.

6543.05 × 2 = 13086.10 B. T. U. per pound as found above.

WATER GAS AND THE DELLWIK PROCESS.*

BY PROF. VIVIAN B. LEWES.

WATER gas, which is the name given to the mixture of gaseous products obtained by the decomposition of steam by incandescent carbon,† consists of hydrogen and carbon monoxide as its main constituents, with traces of carbon dioxide, methane, and nitrogen as its impurities, and the early attempts to make it on a large scale all consisted of retort processes in which charcoal or coke was heated to the highest attainable temperature whilst steam was passing through the incandescent mass. The amount of heat, however, absorbed by the decomposition of the water so far exceeded the temperature generated by the formation of the carbon monoxide that the exterior heat was seldom sufficient to keep the mass at a bright red heat. The temperature of the fuel consequently always rapidly fell, and as it was reduced, so the quantity of carbon dioxide in the gaseous mixture increased, the result being that no continuous retort process has up to the present proved successful. It was only when Gillard, in 1849, first introduced the idea of blowing up the carbon to incandescence by means of an air blast and then steaming the incandescent fuel to form water gas until the temperature fell to the point at which carbon dioxide began to appear that any successful issue seemed probable in forming a completely combustible gaseous fuel from the solid carbon. After many vicissitudes in Europe and America several continental works during the eighties set up generators upon this principle of "blow and run."

The form of apparatus installed consisted of what is practically a cupola furnace lined with fire-brick, and with a constriction a short distance above the hearth, the fire-brick being protected at this point by a water-cooled ring. The usual size of the generator was about 20 feet in height and 7 feet in diameter. An air blast was admitted below the water-cooled ring. By "blowing" for about 10 minutes the ignited fuel was raised to incandescence, when the air blast was cut off and steam admitted above the top of the fuel, and this passing down through the incandescent fuel was converted into water gas, which escaped by the same opening through which the air blast was admitted, the inlet and outlet being opened and closed by means of a water-cooled slide-valve of such construction that it was impossible for any explosive mixture of water gas and air to be formed.

In these installations the fuel is first raised to incandescence by an air blast, which causes the combustion of a portion of the fuel and yields as a gaseous product the so-called producer gas, which has the average composition

Nitrogen	63.64
Carbon Monoxide	29.33
Carbon Dioxide	4.15
Hydrogen	2.88
	100.00

and which, although it only contains about 32 per cent. of combustible matter, can be used as a fuel gas, provided it is burnt while still hot. In order to insure the temperature of the fuel being raised sufficiently high for the production of 1000 cubic feet of water gas, the air blast has to be used for such a lengthened period that no less than 4000 cubic feet of producer gas are formed, which require the combustion of over 44 pounds of carbon from the fuel; and as the 1000 cubic feet of water gas contain about 15 pounds of carbon, it will be seen that each 1000 cubic feet of water gas means the consumption of about 60 pounds of carbon. These data have been calculated from analyses of the producer and water gas, but they have proved correct in practice; and if the percentage of carbon in the coke used be taken in pounds per ton and divided by 60, the resulting figures will approximate very closely to the actual yield of water gas obtained from the particular quality of coke by the old process.

The average yield of water gas per ton of coke may be taken as 34,000 cubic feet. Although some observers have given lower figures, the quality of the coke must be taken into consideration; for instance, with a dirty and crumbly coke a longer blow is required, which of course means increased consumption of fuel. A thousand cubic feet of water gas contain as the combustible constituents—hydrogen 2.75 pounds, carbon monoxide 30 pounds, and the thermal value will be represented by (2.75 × 34400) + (30 × 2400) = 155.600 British thermal units, whilst the thermal value of the 60 pounds of coke used would be 8080 × 60 = 484.800 British thermal units, so that the thermal value of the water gas is only 34 per cent. of that of the carbon from which it was formed. It is this loss which has proved so great a drawback to the economic utilization of the gas. If, however, the producer gas can be utilized while it is hot, another 223.328 thermal units will be obtained, bringing the total calorific value of the two mixtures to 80 per cent. of the value of the carbon consumed in their formation.

If this could have been carried out in practice, water gas would have no doubt proved successful, but when one considers that the processes of making producer and water gas are intermittent, and that four times the volume of producer gas is obtained as of water gas, it is evident that these drawbacks are difficult to overcome, as the producer gas would require enormous storage space, and, after cooling down, is hardly worth burning. When the present process for the manufacture of carburetted water gas was introduced, it at once became apparent that the producer gas, the loss of which had crippled all previous water gas processes, could be utilized for raising chambers filled with chequer brickwork to a high temperature in order to decompose the oils to yield the oil gas which, mixed with the water gas, renders the latter luminous. It was in this way, by making the carburetted water gas plant a perfect heat machine, that its great success was achieved, as in raising the fuel to incandescence the producer gas, with all its heat in it, was at once burnt with a fresh supply of air in the

*Abstract of a paper read before the annual meeting of the Incorporated Institution of Gas Engineers, London, May 1, 1900.

†In European practice, the term "water gas" is used to denote "blue" or "producer" gas, while its popular American acceptance implies that it has been enriched to an illuminating gas.—THE EDITOR.

superheating chambers, the practical loss of heat taking place throughout the whole apparatus being reduced to a minimum.

In 1896 Carl Dellwik introduced a modification in the process of making water gas which entirely altered the whole aspect of the industry. In all previous attempts the incandescence of the fuel was obtained by "blowing" so deep a bed of fuel that carbon monoxide and the residual nitrogen of the air formed the chief products. In the formation of carbon monoxide in producer gas only 2400 heat units are developed per pound of carbon, but if sufficient air be present to burn the carbon to carbon dioxide, 8080 heat units are obtained, an amount which is 3.37 times as great. This is the principle upon which Dellwik devised his process, the main point of which is the adjustment of the air supply to the fuel in the generator in such a way that carbon dioxide is formed instead of carbon monoxide. Under these conditions the producer gas ceases to exist as a by-product, and the gases of the blow consist merely of the incombustible products of complete combustion, carbon dioxide and nitrogen; the result being that more than three times the heat is developed for the combustion of the same amount of fuel, and double the quantity of water gas can be made per pound of fuel than was before possible, and the runs or times of steaming can be continued for longer periods. In the old process it was necessary to blow for nearly ten minutes in order to bring the fuel to the right temperature, while the period of steaming only lasted from four to five minutes, but in the Dellwik process, the "blow" rarely exceeds two minutes, and it is possible to steam for from seven to ten minutes.

At first sight it would appear that this plan must result in the formation of a considerable amount of carbon dioxide, but an examination of the gas soon corrects this idea, as is shown by analyses of samples taken at intervals during a run:

	I.	II.	III.
Hydrogen	52.43	50.09	52.76
Carbon Monoxide	38.30	39.95	37.50
Carbon Dioxide	4.73	5.38	4.08
Oxygen	0.74	1.22	0.46
Nitrogen	3.80	3.36	5.20

and as 5 per cent. of carbon dioxide in the unpurified gas may be looked upon as a fair average when using the old process, these results are distinctly good. In order to make sure that no mistake was being made, analyses were taken during a long series of runs, and also from the gas in the holder when it was found that the average came out at 4.58 per cent., the highest being 4.9 and the lowest 4.2.

The Dellwik process has come at a moment when the general views as to the actions taking place during the combustion of carbon are undergoing a radical change, and no better example could be found to illustrate these views than the cycle of operations taking place in the generator during the two processes of blowing and steaming. The old theory is that when carbon is burnt, carbon dioxide is formed, and that this carbon dioxide in contact with more incandescent carbon becomes reduced to double its volume of carbon monoxide. All that theory is now changed, and the work of Dixon, Baker and others shows that the direct combustion of carbon with oxygen yields only one oxide, carbon monoxide, and that this is the primary product of combustion, whilst this carbon monoxide in contact with oxygen or any oxidizing substance forms carbon dioxide. Working under the old theory, a deep bed of fuel was taken in the generator and the air current was driven into it. It was considered that the dioxide was formed at the bottom of the generator where the air was in excess, and that as the oxygen was used up so the carbon dioxide became reduced to carbon monoxide, which was found in the producer gas in the upper portion of the layer. At the present time we know that as long as there is no air in excess carbon monoxide can be the only product of the action; and in all the old generators a large excess of carbon as compared to the air being present, the temperature which could be produced was merely the temperature of the formation of carbon monoxide.

In the Dellwik plant, however, the conditions are reversed. By lowering the height of the bed of fuel, keeping it at a constant level, and increasing the pressure under which the blast is driven through the heated coke, the air is kept always in excess, so that as carbon monoxide is formed by the primary combustion of the carbon, there is always sufficient oxygen present to oxidize the carbon monoxide to dioxide, and the total heating effect is increased more than threefold for the same combustion of carbon. In this lies one of the great secrets of the Dellwik process, as the fuel burnt for the same increment of temperature is less than a third of that used in the old process.

In the same way our ideas as to the chemical actions taking place during the formation of the water gas as the steam passes over the incandescent fuel during a run need modification. The formation of carbon dioxide in the water gas has always been explained by the assumption that there are variations in the actions which take place according to the temperature of the fuel, and that at high temperatures the decomposition of the steam may be represented as $H_2O + C = CO + H_2$, whilst, as the temperature of the fuel bed falls, the action approximates more and more closely to $2H_2O + C = CO_2 + 2H_2$. This view is, however, incorrect. The carbon dioxide is not formed by the action of steam directly on carbon at all, but by the oxidation of the carbon monoxide first formed, and the actions should be represented by the equations

1. $H O + C = CO + H_2$.
2. $2H_2O + CO = CO_2 + H_2$.

Carbon monoxide begins to decompose steam with conversion into carbon dioxide and liberation of hydrogen at a temperature of 625° C., so that at any temperature above this point and below the temperature at which carbon dioxide dissociates, you always produce dioxide if an excess of steam is used, whilst at any temperature above that at which carbon decomposes steam, carbon monoxide only is formed as long as no excess of steam is present.

The result of this is that if as the temperature falls and the area of carbon sufficiently heated to decompose the steam becomes less and less, we reduce the inlet of steam in a slightly greater ratio, it is possible to make water gas from end to end of the run without any carbon dioxide at all, the only secret being that no excess of steam shall be present at any period of the operation.

This beautiful welding of theory and practice in this form of generator gives us the power of producing 70,000 cubic feet of water gas per ton of carbon as against 34,000 cubic feet with the old process In consequence a most important cheapening in the manufacture of the gas is achieved; and water gas is now the most important factor for economically obtaining high temperatures that the world possesses.

THE RELATIONS BETWEEN ELECTRICITY AND ENGINEERING.

(Continued from page 101.)

enemy's ships are properly located by position finders, is the last development of the application of electricity to war.

Electrical blasting has revolutionized the operations of tunneling and driving galleries. It is much used in quarrying with great security to the men.

The deepening of harbors and channels and the removal of obstructions, such as wrecks and rocks, are facilitated. On September 23, 1876, 63,135 cubic yards of solid rock were completely demolished by one discharge at Hell Gate, in East River, New York. The preparation for this great blast took four years and four months. There were 4427 charged holes, each containing its mercury fulminate fuse and charges of dynamite. There were 49,914 explosions used in that one blast. Batteries were used to generate the currents, and they were arranged in large groups. Each battery exploded 160 charges. This was the record blast.

The battleship is the home of electricity. It controls the rudder, it ventilates the interior and the living space of the ship, it forces the draught and assists the raising of steam, it revolves the turrets, it trains and controls the fans, it handles the ammunition, it purifies the drinking water, it lights up the ship internally, it en-

ables the captain to sweep the horizon with the brilliant rays of the searchlight, and to communicate with his tender or with his commanding officer across space independent of weather, night, season, fog or rain.

SANITATION.

No branch of our profession fulfills the true function of the engineer more efficiently than that which deals with sanitation. Pure air, pure water, pure food, pure soil, pure dwellings and pure bodies are the panacea for health and comfort. Electricity helps us very much in attaining some of these qualities. An electric incandescent lamp does not vitiate the air. It does not throw into circulation in the air any product of combustion. The question of ventilation is very much reduced in importance and rendered more simple to effect. Much less air need pass through our sitting-rooms and meeting places. The air vitiated by our lungs can be easily withdrawn and fresh air can be forced in by fans worked by electric motors. Even the air during its entrance can be warmed, and impurities floating in it can be sifted out of it by the attraction of electrification.

Heating by Dowsing's luminous electric radiators is very much on the increase; they consume 250 watts, which cost about ½d. per hour. In many postoffices sealing-wax is melted and kept in a liquid state by currents. Water can be sterilized by ozone, a product of electrification, and even by the nascent oxygen, when broken up into its constituent elements by electric currents. Sea water thus electrolyzed supplies us with chlorine, and converts the water into a powerful antiseptic, disinfectant and deodorizer. Its economy is, however, doubtful, and in consequence its adoption has been much restricted.

INDUSTRIES.

The applications of electricity to other industrial processes are innumerable. I have time to mention only one. T. A. B. Carver, who was a pupil of Lord Kelvin and an officer on our staff in this Institution, has brought out a new Jacquard loom for weaving; 600 hooks are controlled electrically. The twill as well as the pattern is under complete management. It has been warmly taken up in Glasgow, and a factory has been started there. The pattern on this cloth is woven directly from a photo-print of the artist's design, mounted on a metallic sheet, the threads of the warp being picked up by electro-magnetic action, owing to the figure of the pattern being cut away, and thus allowing the circuit to be completed by the metallic sheet.

The theme of the relations between electricity and engineering is too great for an hour's discourse. Electricity tends to economize labor and to cheapen the cost of living. It increases national wealth, and promotes international friendship. It enlightens the invisible, and it alleviates suffering. It conduces to avert war, and it certainly facilitates the conclusion of peace. Its practical applications have run *pari passu* with our revered Queen's reign. They are growing with great rapidity. Who can forecast the future? One simple lesson that I have learnt is that in the practical developments of electricity the only thing that occurs is the unexpected. There is now a distinct line of demarkation separating the physicist from the engineer. The former dives into the unknown to discover new truths; the latter applies the known to the service of man. Research is the function of the one, utility that of the other. In the past the engineer has had to rely on himself for his facts, but the advance of modern science, the growth of technical education, the formation of laboratories, and the endowment of chairs have changed all that. We can scarcely hope for new sources of energy to be discovered, but there are some existing ones we have not touched yet. When the evil day arrives for our coal supplies to give out we may perhaps be able, by the aid of electricity, to utilize the heat of the sun and the tides of the ocean. There is, however, a vast illimitable store of energy not only in the rotation of the earth upon its axis, but in the internal heat of the globe itself. As we descend the temperature gets higher and higher. It ought not to be difficult to reach such temperatures that by thermo-electric appliances we might convert the lost energy of the earth's interior into some useful electric form.

THE POWER IN A POUND OF COAL.*

BY E. D. MEYER.

LET us take a pound of what we will call average coal, containing, say, 10,000 heat units. This would be somewhat smaller in size than a man's fist. A pound of this coal, if expended in mechanical work, would give us 236 horsepower.† Imagine at the time of the Pharaohs two long lines of men, extending over half a mile, all pulling steadily, at the command of the task-master, at a great rope to raise some huge obelisk, and as you see them sweating, tugging and straining, think again of this small lump of coal in which nature has placed an equal amount of power. In some countries men who have been specially trained as porters to carry heavy loads on their backs, will, as a full day's work, carry a total of from 350 to 600 pounds a distance of one mile. And yet each has expended but one-third of the power stored up in this pound of coal.

An exceptionally strong man has been known to do one-half horsepower of work as his mightiest effort; but in two and a half minutes, work at this rate exhausts his muscular force. Let us suppose 100 such men putting forth such extreme effort at rope, or crank, or crowbar; as they fall back, red-faced and puffing, to catch their breaths, we might imagine this little black lump saying to them: "I can do as much as your whole company, and then can stand it for fully two minutes longer before I am exhausted."

Let us now turn to another portion of the human race. From the earliest times spinning has been a much-prized accomplishment of the fair sex. We need look back only to our own grandmothers. We can picture them, from their own stories, told us when we were children, as rosy-cheeked damsels sitting around the open fire-place and spinning from early candlelight till bedtime, let us say possibly two hours. Let us then consider for a moment the thousands of spindles rattling and whirling in a modern cotton factory, impelled by the power locked up in coal. One pound of this coal carries the potential energy to do the work of 3000 such spinsters.

In sawing wood, a man may work at the rate of about 60 strokes a minute and consider himself a "top-sawyer," and his saw blade may have progressed five feet a minute; but a circular saw, driven by machinery, may be put through 70 times that distance and saw 70 times as much wood. And yet this one little pound of coal contains power enough for 180 such saws.

COPPER ECONOMY OF DIFFERENT SYSTEMS.

HANAPPE, in a serial recently published in a French contemporary (*L'Eclairage Electrique*) gives a comparison of the quantity of copper necessary for the line in the principal continuous, single-phase and polyphase-current systems. The power transmitted, the length of the line and the loss by Joulean heat are supposed to be equal in all cases; the first part of the article deals with long-distance, high-pressure transmissions; the second with power distribution at the ordinary voltage of the receiving circuit. These two cases, which are shown in columns A and B respectively, are dealt with for nine different systems and the results are given in a table, as follows:

	A.	B.
Continuous current with two wires.....	100	100
" " with three wires	125	31.25
Alternating current with two wires.....	200	100
" " with three wires....	250	31.25
Two-phase current with four wires	200	100
" " with three wires. ...	291.4	72.9
Three-phase current, star connected without neutral wire....	150	25
" " star connected with neutral wire	175	29.2
" " ring connected	150	75

**Cassier's Magazine* for May—abstract.

†Obviously, the very interesting calculations made by the author take no cognizance of the element of time.—THE EDITOR.

The numbers in this table give the relative quantity of copper necessary for each system, if that for the continuous-current system with two wires is assumed to be 100, and if the same power is transmitted over the same length of line with the same loss of power by Joulean effect. In the first column of numbers the maximum voltage between the wires is supposed to be equal, in the second column the effective voltage at the receiving end.

COEFFICIENTS OF EXPANSION.

THE reader of the JOURNAL who has asked for information regarding some book or publication that will give him accurate physical formulæ and constants, is referred to the eighth edition of Jones' "Logarithmic Tables," which has just been published and the price of which by mail is one dollar. Information in particular was desired regarding coefficients of expansion and formulæ for the calculation of lengths of expansion under different temperatures. The work referred to shows that if temperatures be measured in Centigrade degrees, lengths at temperature $t°$ are expressed in terms of the lengths at 0° by the formula

$$l_t = l_0 (1 + a\, t),$$

and volumes by the formula

$$V_t = V_0 (1 + 3\, a\, t).$$

If the Fahrenheit scale be used, these formulæ become

$$l_t = l_{32} [1 + a' (t - 32)], \quad V_t = V_{32} [1 + 3\, a' (t - 32)].$$

The constants a and a' are as follows:

	a		a'	
Aluminum	.0⁴231–	.0⁴235	.0⁴128–	.0⁴130
Bismuth	132	133	073	074
Brass	184	191	102	106
Brick	054	090	030	050
Cadmium	307	316	170	175
Carbon, gas coke	054	055	030	031
graphite	079		044	
Copper	167	172	093	106
Glass	070	092	039	051
Gold	144	147	080	081
Iron, cast	117	144	065	080
steel	110	122	061	068
wrought	108	117	060	065
Lead	280	312	155	160
Magnesium	269	276	149	153
Nickel	128		071	
Platinum	088	091	049	051
Silver	192	194	107	108
Stone	045	117	025	065
Tin	223	233	125	160
Wood	036	063	020	035
Zinc	290	298	160	165

DUST ON ELECTRIC LIGHT WIRES.

Without doubt the deposition of dust on one of the leads of the exposed interior wiring on direct-current wires described by a correspondent in the last issue of the JOURNAL (page 86), is due to the electrostatic attraction of that particular wire. Moreover, the fact that the other wire does not gather dust proves that it is grounded — probably that it is the neutral of the three-wire system, the first wire being positive.

The use of a main switch will reduce the tendency of the positive wire to gather dust simply by keeping potential off the circuits except when in use, but there is no known way for entirely obviating it.

R. F. MARKHILL has resigned from the service of the West Kootenay Light and Power Company, Ltd., at the Bonnington Falls power house and has gone to St. Johns, Newfoundland, where he has taken charge of the St. Johns sub-station of the new electric power transmission which has entered that city.

"The JOURNAL is an important factor in the development of the Pacific Coast."—*Western Electrician.*

Literature.

ELECTRIC POWER TRANSMISSION, by Louis Bell, Ph. D., Memb. Am. Inst. Elec. Engrs. Second edition; revised and enlarged. Size, 9x6 inches, 505 pages, 243 illustrations, 8vo, cloth. Published by the *Electrical World and Engineer*, New York, 1899. Price, $2.50

The clear, lucid style which has always characterized Dr. Bell's discussions of electrical engineering subjects has placed him in the front rank of American electro-technical writers. More than this, his writings are so thoroughly and evenly tempered with sound theoretical training, broad practical experience, and unequaled opportunities for observation that, when these qualifications are coupled with the conviction that a single idea intelligently conveyed is better than a world of wisdom expressed in riddles, his book will be found to be a model of comprehensiveness and readibility.

Bell's "Electric Power Transmission" sets forth in the simplest possible manner the fundamental facts concerning present practice in this now most highly important branch of engineering. The author truly points out in the preface to the first edition of his work that busy men have little time to spend in discussing theories of which the practical results are known, or in following the deviation of formulæ which no one disputes; therefore he has endeavored with eminent success to introduce only such theoretical considerations as are absolutely necessary, to explain them in the most direct mode possible, and to present cold engineering and commercial facts in a way that shall be at once clear, convincing and practicable. Again, the four years that have passed since the first edition of the book was brought out have developed but really few changes in the art of electrical power transmission. Voltages in commercial use have risen to 40,000, the distance of transmission has been increased to 82 miles, and the applications of electrically transmitted power have become so universal that they have entered into every conceivable form in which electricity is used; but even so, there never was the slightest doubt regarding the early attainment of these results for fully the last half-decade. Beyond this, new knowledge has been mainly gained along the line of ascertaining more definitely the commercial and technical limitations of the art. Scott's beautiful researches in high-voltage phenomena, as brought out in his Institute paper,* are of the greatest practical value and indicate the limits of the dielectric strength of air which, more than anything else, will restrict the use of extreme high potentials. Of course, some changes have occurred in transmission practice during the last four or five years, and these are fully noted in the second edition of Bell's book.

At the outset the author discusses such elementary principles as pertain to the science of electrical transmission, whence prime movers are reviewed as well as the various forms of power transmission, such as wire rope, hydraulic power, compressed air and gas transmission. Next the subject of electrical transmission by continuous current in both constant-current and constant-potential forms is taken up and treated mainly from the standpoint of central station practice, although the constant-current transmission at Genoa, comprising about 1000 horsepower at from 6000 to 8000 volts, is described in some detail, as are also several constant-potential, direct-current transmissions in Europe. Chapter IV presents the theme, "some properties of alternating currents" in a very clear and attractive form, despite the use of algebra, which it really seems impossible to dispense with. The reader is then led into alternating-current transmission practices — and not a step is taken blindfolded. One wonders, however, that the author should leave the inference with the reader that the Fort Wayne self-starting

*Transactions A. I. E. E., Vol. XV, page 673, October, 1898. Reprinted in abstract in the JOURNAL, Vol. VI, page 113, December, 1898.

single phase motor has a place in the markets of industry—but hold; it has! The junk shops of San Francisco are glutted with them waiting to be sold at the current pound rates for scrap—and no buyers We can forgive the author for this inference, however, for at worst it is but a sin of omission—not commission.

The majority of transmissions described are those which are most prominent on the Pacific Coast, among which are named those at Walla Walla, Sacramento, Portland, Fresno, Bodie, Pomona, Redlands and Los Angeles (Southern California transmission). No material mention is made of the San Gabriel transmission although it is in many regards one of the most remarkable to be found in American electrical engineering practice. Neither is the Niagara plant discussed with the fullness which it would seem that its importance warrants and—though it may perhaps be unbecoming to say so—the fact is that the descriptions which the author gives of the engineering features of these transmissions of the West do not compare at all favorably with those which have appeared in the columns of the JOURNAL either in fullness or in beauty of illustration or in point of thoroughness of technical detail. The author's descriptions are good so far as they go, but they merely give a synopsis of the whole situation—barely a prologue of the actual performance, as it were.

Of especial importance are the chapters on the line, line construction and on local distribution, the failure to thoroughly digest which should be considered high treason in electrical transmission circles. Many of the formulæ therein given will probably become standard in electrical transmission work; such, for instance, as his stock formula for the calculation of three-phase lines, which is given on page 403, wherein he substitutes $\frac{\text{Watts}}{\text{Volts}}$ for the current factor in a more familiar equation, whence is derived the formula:

$$c.\,m. = \frac{D \times 11 \times \frac{W}{V}}{V_1}$$

wherein D is the distance of transmission, W is the watts received, V is the voltage of reception, and V_1 is the volts lost in the line.

But to go into detail regarding the points there brought up, dissected and analyzed, is beyond a reviewer's province, hence suffice it to say that the subject is covered in Dr. Bell's happiest way—and that is saying a very great deal in praise of it. The work concludes with a list of plants operating in North America at 10,000 volts or more, including the kilowatt capacity, the length of line, the line voltage and the periodicity of each, the list being practically up to date.

TRADE LITERATURE.*

Bullock Bulletin. No. 32a. "Direct-Current Multipolar Motors, ' type H; described with data and efficiency curves. *Bullock Electric Mfg. Co.*, Cincinnati.

"Marine Electrical Apparatus." One of the exquisite brochures popularly descriptive of the development of electric light and power to marine work and especially to satisfy the exactions of naval requirements. Lavishly illustrated, many cuts being of vessels of the United States Navy. Catalogue No. 1025. *General Electric Co.*

General Electric Bulletins. No. 4217, "The GE-57 Railway Motor," of somewhat greater capacity than the well known GE-1000, and adapted for use on a minimum gage of 48 inches, with or without electric brakes; Nc. 4218, "Type MR Feeder Potential Regulators," in new, enclosed and oil-cooled form. *General Electric Company.*

"A Treatise on Wood Preservation," being investigations by eminent German Scientists and authorities on this subject, with special reference to the Hasselmann system of impregnation. The chief contributors to the pamphlet are Dr. J. E. Weiss, professor at Lyceum in Freising, and Joseph Beibinhaus, Royal Engineer and Director of the Royal Bavarian R. R. Impregnation Department; Dr. Max Krause, M. E. 32 pages, 3x6 inches, 1900. *Barschall Impregnating Company*, 31 Nassau street, New York.

"Biddle's Bulletin." This is a monthly record published in the interest of those who use scientific, and especially electrical, instruments. Although its purport is avowedly to increase "Biddle's business," yet the matter it contains is of such exceeding value that it seems almost a sacrilege to class the work among advertising circulars. It is such, however, but nevertheless "Biddle's Bulletin" bids fair to soon be recognized as the standard publication for the specialization of electrical instrument details, designs and characteristics of operation. Annual subscription, 50 cents, which, presumably, is only nominal. Published by *James G. Biddle*, 1038 Drexel Building, Philadelphia.

Westinghouse Bulletins. No. 1015, "Transformer Fuse Blocks," for from 1000 to 3000 volts, iron clad, single and double pole and detachable fuse-holders; No. 1016, "The Electro-Magnetic Traction System," recently developed by the Westinghouse companies for the purpose of avoiding the use of overhead wires or underground conduits. The connections between the cars and the supply circuit is made entirely on the surface, hence the name of "surface contact," frequently given, but the more proper name is "electro-magnetic" system. Fully described with essential details, and particularly adapted for yard work or wherever overhead wires are not permissible. No. 1017, "Alternating-Current Potential Regulators," for single-phase and polyphase circuits. A general treatise, with data, of Stillwell polyphase and special regulators. *Westinghouse Electric and Mfg. Co.*

*Catalogues mentioned in this department will be mailed gratuitously on application to the concerns publishing them. When writing, mention THE JOURNAL OF ELECTRICITY, POWER AND GAS. Where addresses are not given, they may be found through reference to the Advertisers' Index on page v.

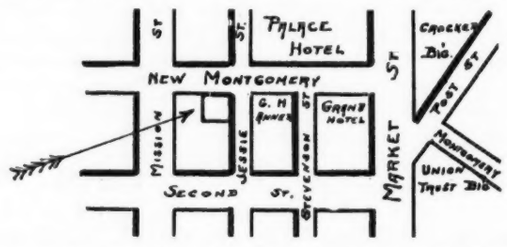
Industrial

In responding to advertisements in this publication kindly mention "The Journal of Electricity, Power and Gas."

THE NEW OFFICES OF JNO. MARTIN & CO.

John Martin's electrical agencies, principal among which are the Pittsburg Reduction Company, the Stanley Electric Manufacturing Company and Fred M. Locke, are now carried by the firm of Jno. Martin & Co., which has succeeded to Mr. Martin's electrical agency interests but in which he holds the dominant influence.

After June 1st, the offices of Jno. Martin & Co. will be located at 31-33 New Montgomery street, San Francisco, in the



corner of the building formerly occupied by Wells, Fargo & Co's. Express. The new location, in addition to being well within the electrical center, is, as appears in the accompanying cut, most convenient to the principal hotels and leading thoroughfares. The offices are luxuriously furnished, and, as heretofore, every facility will be found to enable all who call to feel thoroughly at home.

"The JOURNAL has received no little attention."—*Electricity.*

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